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Prospective Study of Burn Wound Excision of the Hands

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To examine the role of early excision and grafting in the preservation of maximal function of hands with deep dermal burns, we prospectively evaluated 164 burned hands in consecutively admitted patients (mean age, 29 years; mean burn size, 37% of body surface). All hands with burn depths of second degree, deep second degree, or third degree above the level of the tendons and joint capsules were assessed preoperatively, intraoperatively, and at discharge from the hospital. Patients were treated by excision and grafting in the first or second postburn week, by delayed grafting alone, or by allowing primary healing. Total active range of motion measurements were made on the day of discharge (mean, 64th postoperative day). Mean operative blood loss per hand was 1,270 ml. When all (alive and dead) patients undergoing early excision and grafting were examined by a binomial probability model, early surgery was shown to produce no adverse affect on survival. Excision and grafting of hands with deep dermal burns, whether early or late, offered no advantage over physical therapy and primary healing in maintaining hand function. Likewise, hands with more superficial burns responded equally to operative and nonoperative treatment. While early excision and grafting of hands with third-degree burns tended to produce poorer results than did initial nonoperative care and late grafting, the differences are just outside the range of significance. Early excision and grafting of selected third-degree injuries of the hands may be indicated in patients with small total body surface burns in order to shorten hospital stay. However, early surgical intervention in patients with massive burns should be directed toward area coverage, not toward hand excision.

While rarely life threatening, burns of the dorsum of the hand can produce deformities and loss of function which are often the most devastating sequelae of a thermal injury. The neglected burned hand characteristically assumes a permanent claw posture, and this intrinsic minus deformity presents with permanent hyperextension and often subluxation of the metacarpophalangeal joints and fixed flexion of the interphalangeal joints. Deep dorsal hand burns which destroy the extensor mechanisms and extend into bone respond poorly, if at all, to any therapy aimed at restoring motion and function, and treatment is directed toward minimizing subsequent deformity. Superficial second-degree burns characteristically heal early and are not associated with loss of motion. In between these two extremes, the outcome of partial-thickness and full-thickness cutaneous burns of the dorsum of the hand is affected appreciably by subsequent therapeutic interventions. In recent years, two philosophies for the treatment of burns of the dorsum of the hand have evolved: the early surgical approach with excision and autografting, and the conservative nonoperative approach allowing spontaneous healing and later resurfacing, if needed. Before the availability of topical antibacterial agents, burn wound infection was common, and early excision and autografting were widely practiced to reduce the rates of wound infection and to improve graft take (3, 12, 14). With the development of effective topical antimicrobial chemotherapy, infection in the burn wound usually could be controlled, and a more conservative 'wait and see' approach was adopted by many in the treatment of dorsal hand burns (13, 15). Interest in early excision and autografting has been rekindled by the recent introduction of tangential excision (10, 11). This method allows the sequential removal of nonviable tissue and facilitates the preservation of the underlying extensor tendon mechanisms of the hand.

The precise role of early excisional therapy remains ill defined. Some proponents feel that surgery should be carried out within the first postburn week, while others wait until the second postburn week (2, 4, 5, 7–9, 19). A number of advantages accrue to early excision and im-

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mediate autografting of dorsal hand burns. This surgical approach achieves early closure of the burn wound before the wound colonizes with bacteria and infection ensues. The infected hand is difficult or impossible to graft, and should this complication occur, long delays to eventual closure, loss of motion, and deformity are not uncommon. If the dorsum of the unburned hand is tangentially excised during the period of maximal tissue edema (postburn days 3 through 7), the surgery is often easier, faster, and safer, since the burn tissue is elevated away from the underlying tendons and joint structures. Grafting virtually eliminates the pain associated with that portion of the burn, and mobilization and early use of the hand for eating and other functions may be facilitated.

Early excision and grafting is associated with a number of disadvantages. Assessment of burn depth is difficult, especially if surgery is carried out within the first 3 to 5 days following burn injury, and viable tissue may be excised along with the nonviable wound (4, 8). The skin overlying the dorsal surfaces of the hand and digits is quite thin, and injury to the underlying extensor mechanisms may occur, especially when surgery is carried out by relatively inexperienced personnel. The skin graft may be lost, and if a deep thermal partial-thickness wound has been excised, a full-thickness defect now remains. Of equal and perhaps greater concern, early grafting of the hands of patients with large life-threatening thermal injuries robs the patient of donor sites which should be used for broad surface coverge to reduce the overall size of the burn injury. In addition, early operation usually requires general anesthesia and results in considerable blood loss, and this additional stress, plus the added burden of new donor wounds, may precipitate hemodynamic decompensation, especially in elderly patients.

The nonoperative approach to initial burned hand care avoids many of the disadvantages of early surgery listed above, allows spontaneous healing, and requires later grafting of only full-thickness areas of skin loss. However, this technique is not without its drawbacks. As long as the wound remains ungrafted, it is painful and often discourages patient cooperation with physical therapy and support functions such as eating and grooming. The risk of infection is always present as long as the wound remains unhealed. A certain amount of edema persists in the underlying tissues, and this protein-rich fluid may predispose to the formation of tissue fibrosis and limitation of motion (16). However, with elevation, compression garments, and modern protocols for physical therapy, this latter objection may be minimized.

Both treatment modalities offer theoretical benefits, but little or no data exist which document the superiority of either technique in preserving hand function. This study was instituted to ascertain the more effective method of management by following all patients with treatable hand burns through the complete hospitalization and quantifying hand function at the time of discharge.

MATERIALS AND METHODS

The study population consisted of all burned patients who were admitted during a 3-year interval and who had burns of the entire dorsum of the hand and all digits. Immediately following admission, patients were resuscitated by the modified Brooke formula, 2 ml/kg per per cent burn of lactated Ringer's solution during the first 24 hours, followed by replacement of plasma volume deficits on the second postburn day (17). Patients received routine general supportive care as indicated.

Immediately following admission to the burn center, all hand burns were examined for potential inclusion into this prospective study. Hands thought to have superficial second-degree burns which would heal rapidly were not entered into this study. Likewise, hands with obvious deep injury causing thrombosis of subcutaneous veins, involvement of the extensor mechanism, and charring of the digits were excluded from this analysis. Hands with deep dermal or full-thickness burns were retained in the study population and are the basis for this report.

Most patients treated with early excision and grafting were operated on within the first postburn week. However, surgery was delayed in nine patients until the second postburn week because of later transfer to our treatment facility. Following admission to this Institute, each patient was assigned to an individual surgeon for all of his in-hospital care. The choice of early excision and grafting or initial nonoperative treatment was left to the discretion of the patient's primary physician. Although some surgeons avoided early surgery in patients with inhalation injury, others did not. No specific consideration was given to the size of the total body thermal injury in selecting the patient for either of the two forms of treatment. Assessment of the accuracy of the initial estimation of burn wound depth in patients undergoing early excision and grafting was verified in the operating room. The depth at which punctate bleeding occurred following tangential excision was used as the final criterion of burn depth. If burn injury remained superficial to the extensor paratenon and the overlying venous plexus, the burn was judged to be confined solely to the cutaneous tissue and the patient was retained in the study. If the injury caused thrombosis of the venous plexus over the paratenon, especially at the proximal interphalangeal joint, the extensor mechanism usually was destroyed and the patient was eliminated from the study. Because of the initial selection process on admission, such deeply burned hands were rarely operated. All tissue excised from the dorsum of the hands and digits was examined histologically and the depth of injury was confirmed. Histologic examination was particularly useful in separating deep dermal injury from that of a more superficial variety. Confirmation of the initial admission

estimate in patients being treated conservatively was based on the degree of spontaneous healing. If dorsal hand burns healed totally within 2 to 3 weeks, these were judged to be partial-thickness injuries. Hand burns resulting in the development of mature eschar and the subsequent formation of granulation tissue were judged to be full-thickness injuries. A small group of patients healed primarily over most of the wound but retained small areas of granulation tissue where full-thickness injury obviously has occurred. This group represents a slightly deeper injury but was included in the patient group with deep dermal burns.

Management of the hand burns was carried out in a standardized fashion. Immediately following injury, blood flow to the upper extremity was assessed hourly by digital palpation and Doppler ultrasonography. Escharotomies of upper extremities were carried out if pulses in the major vessels at the wrist or along the palmar arch disappeared. Digital escharotomies were rarely utilized. The burn wounds, including those of the hands, were covered with a topical antimicrobial agent (silver sulfadiazine or mafenide acetate) at all times and left exposed. Topical enzymes were avoided. All burned extremities were elevated on specially constructed slings attached to IV poles. Before surgery, all patients received prophylactic antibiotics, usually penicillin or a combination of amikacin and vancomycin. A general anesthetic, or less often, an axillary block, was utilized in those patients undergoing early excision and grafting. Tourniquets around the upper extremities were rarely used. Patients with bilateral hand burns usually underwent simultaneous excision and grafting of both hands by two surgical teams. Using a Humby knife or a Goulian-Weck dermatome, sequential tangential excision was carried down to viable dermis or fat as indicated by profuse punctate bleeding. In some cases, it was necessary to excise fat down to viable paratenon, but care was taken to preserve the extensor hood and tendons, especially at the proximal interphalangeal joint. Hemorrhage into injured tissue usually indicated its nonviability, and the excision was carried beyond this level of injury (9). The excision was extended into the web spaces when injured, and also around the lateral margins of the hypothenar and thenar surfaces; however, the palm was not excised primarily. Full-thickness palmar injuries were allowed to debride and granulate and were grafted later in the postburn course. Hemostasis was obtained with topical thrombin and the application of warm, moist sponges, followed by mild compression wrapping and elevation. Electrocoagulation of bleeding points was studiously avoided. Although the excised area was autografted with sheet graft in some patients, most wounds were covered with unexpanded 1.5:1 mesh graft applied longitudinally in rectangular sheets extending out onto the surface of the digits. Care was taken to overlap the separate sheets of autograft so as not to produce a gap of unexposed tissue as the grafts became attached to the underlying wound. The grafts were not secured by sutures, although recently small skin staples have been utilized in some cases to assure precise application. Prophylactic pin fixation of joints was not utilized (1). The wounds were covered with a layer of fine mesh gauze, on top of which were placed sponges soaked in a solution of 5% mafenide acetate. The hand was placed in a custom-made orthoplast splint, which maintained the hand and fingers in an 'anticlaw' position, and the digits were maintained in position by fingernail hooks, which had been glued in place prior to surgery and to which rubber bands were connected. The grafted hand was first inspected on the third postoperative day, at which point gentle physical therapy was begun. The hand was then rewrapped and the process repeated daily for the next 4 days, after which all dressings were removed and a more vigorous physical therapy program was instituted.

Initial treatment of burned hands in the nonoperative, conservative group consisted of daily cleansing and hydrotherapy, eschar debridement, continuous topical antimicrobial chemotherapy, intensive physical therapy (described below), and later, biologic dressings. When the eschar had completely separated and a healthy bed of granulation tissue had formed, the wound was closed with autograft. The newly grafted areas were then treated as described above for initial excision and grafting. When all grafts had become fully adherent, the patients' hands were fitted for compression garments.

The primary goal of physical therapy of dorsal hand burns was the maintenance of function, and a program consisting of range of motion exercises, muscle strengthening procedures, and splinting to maintain proper position was individualized to the particular needs of each patient. Immediately following admission, the physical therapist evaluated sensation and measured the active range of motion of all burned hands. The importance of frequent active exercise and the consequences of inactivity were explained to the patient at the time of initial evaluation. The patient's upper extremities were elevated continuously to assist in the control and subsequent reduction of edema. Forty-eight hours following injury, all burned hands with full-thickness or deep partial-thickness injuries were placed in splints. Splinting devices were not applied during the first 2 postburn days in order to avoid a tourniquet effect during the period of fluid resuscitation and rapid edema formation. Splints maintained the hand in 30° of wrist extension, 75 to 90° of metacarpophalangeal flexion, and full extension of all interphalangeal joints. The thumb was abducted and extended in order to maintain the web space. Splints were applied only during periods of sleep, and exercise and activity were encouraged while awake.

In patients with partial-thickness hand burns not undergoing early excision and grafting, exercises were begun on the day of admission with active fist making. Passive exercises were avoided although in some patients some exercises were gently assisted once active motion

was established. Metacarpophalangeal joint flexion with the proximal interphalangeal and distal interphalangeal joints in extension (tabletop maneuver) was carried out actively. Active proximal interphalangeal and distal interphalangeal flexion was accomplished with the metacarpointerphalangeal joint stabilized in 75 to 90° flexion. Full thumb and finger extension, abduction, and adduction was encouraged. Thumb opposition to all digits was utilized to maintain the transverse and longitudinal arches of the hand. This exercise was often limited by edema and gentle assistance was utilized within the limits of the swollen tissues. Full wrist motion was accomplished actively, with assistance if necessary. Patients with full-thickness hand burns managed by initial nonoperative therapy were treated more cautiously than those with partial-thickness injuries. In such cases, with the exception of metacarpophalangeal joint flexion, all exercises of the fingers were performed actively, and no passive assistance was allowed. Gentle assistance was offered only with metacarpophalangeal flexion, with the assistance being provided at the proximal phalanx. Active thumb mobility was encouraged with particular attention directed toward maintaining the first interosseous web space. Wrist motion was active, with gentle assistance as indicated.

Following application of autograft at any time during the postburn hospital course, hands were immobilized for 3 days and no exercises carried out. Dressings were removed on the third postoperative day, and the surgeon determined when active range of motion commenced. Under most circumstances, gentle active range of motion exercises with minimal repetitions (three to five) were carried out on the third and fourth postoperative days. Upon completion of the exercises, the splint and wound dressings were reapplied. On the fifth and sixth postoperative days, gentle active and active-assisted motion was initiated and the patient began the usual activities of daily living (self-feeding). Splints were applied ony at night. During the seventh through tenth postoperative days, full active motion was expected and an increasing activity level was encouraged. Night splints were continued during this interval. After the tenth postoperative day, usage of splints was discontinued, and all daily activities were encouraged. Muscle strengthening exercises were initiated at this time and maintained throughout the remainder of hospitalization.

All patients entered into this prospective study were measured for active range of motion within 24 hours of discharge from the hospital. Joint mobility was measured with a standard stainless steel finger goniometer (J.A. Preston, Model PC 5048). To provide descriptive data which would reflect functional outcome, the active range of motion of each digit was calculated as the sum of the total flexion of the digit minus the combined lack of extension of all joints of the digit (20). Significant hyperextension at any joint, especially in the proximal interphalangeal and distal interphalangeal joints, was calculated as a deficit in extension and is included in the total extension deficit.

Normal total active motion for the fingers is 250 to 270°, and greater than 210° is associated with excellent function. Normal total active motion for the thumb is 115 to 130°, while that for the wrist is 130 to 150°. Statistical differences between treatment groups were evaluated by analysis of variance. A difference occurring with a probability of less than 0.05 was considered to be statistically significant. The effect of early excision and grafting on patient survival was assessed by a binomial probability model based on age and total body burn size. This model estimates the predicted incidence of mortality and the 95% confidence interval of that prediction.

RESULTS

Ninety-eight patients with a total of 164 burns of the dorsum of the hand fit the criteria for inclusion into this prospective study. Their mean age was 28.9 years (range, 1 to 65 years) and their mean burn size was 37.1% of the body surface (range, 3 to 81%); only five patients were less than 16 years of age. Both hands were burned in 66 patients, while only one was injured in the remaining 32 patients. This propensity for both hands to be involved together in thermal injuries has been noted in other studies (14).

Dorsal hand burns were treated either by early excision and autografting (E and G) or by delaying surgery and allowing spontaneous separation of nonviable tissue (nonoperative). A few patients with bilateral hand burns had one hand excised and grafted early and the other treated expectantly, but the vast majority of bilateral hand burns were treated simultaneously by the same technique. Sixty-seven patients were treated by early excision and grafting of their burned hands (Table I). Not included in this study group are an additional 16 patients receiving the same treatment who died during their hospitalizations (Table I). The nonsurvivors were older (38 vs. 28 years) and had sustained much larger burns (55 vs. 34% of the body surface). All of the patients dying of their injuries had associated inhalation injury, while this complication occurred in only 25% of the operated survivors. Blood replacement at the time of early surgery was 1,268 ± 724 ml (mean ± SD). Thirty-

TABLE I
Characteristics of patient treatment groups

	Early Excision and Grafting		Nonoperative
	Survivors	Nonsurvivors*	
No. of patients	67	16	31
Age (years)	28 (3-62)	38 (13-71)	31 (1-61)
Burn size (% TBS)	34 (3-80)	55 (22.5-71)	42 (10-81)
Full thickness (% TBS)	15 (0-73)	37 (11.5-71)	23 (0-55.5)
Inhalation inhury (%)	25	100	61

Mean (range).
* These patients not included in hand function analysis.

one patients were treated by initial nonoperative management of their hand wounds (Table I). With the exception of size and the incidence of inhalation injury, the two treatment groups (83 vs. 31 patients) were essentially similar.

Forty-one hands proved to have superficial second-degree burns by direct inspection at surgery (with histology documenting injury through epidermis and outer layer of the dermis) or by complete healing within 2 weeks of injury. Nineteen hands were treated by early excision and grafting, and at the time of discharge the total active motion of the wrist and each digit (expressed in mean degrees ± SD) was: W–126.0 ± 33.5; 1–113.1 ± 19.1; 2–237.8 ± 42.6; 3–251.9 ± 37.4; 4–254.3 ± 27.1; and 5–230.9 ± 49.9. Similar measurements in the 22 hands treated nonoperatively were: W–139.4 ± 18.1; 1–109.6 ± 16.3; 2–240.0 ± 16.3; 3–252.5 ± 27.2; 4–252.5 ± 26.6; and 5–245.7 ± 36.3. No digits among these patients required fixation pins. Either method of treatment produced statistically identical preservation of function in hands with this level of thermal injury.

Deep partial-thickness injury was identified by operative findings or by clinical course (incomplete healing by postburn day 14). Excision and grafting of 46 hands was carried out during the first postburn week. Total active motion for these hands was: W–120.9 ± 23.4; 1–101.3 ± 14.6; 2–228.4 ± 46.6; 3–242.9 ± 56.6; 4–242.3 ± 53.5; and 5–237.2 ± 57.0. Similar measurements for the nine patients excised and grafted during the second postburn week were: W–123.3 ± 26.4; 1–126.1 ± 48.1; 2–228.9 ± 36.6; 3–245.0 ± 36.9; 4–237.7 ± 36.4; and 5–229.4 ± 46.6. Fifteen hands were allowed to heal spontaneously. The total active motion in these hands was: W–137.9 ± 16.0; 1–111.4 ± 24.8; 2–247.8 ± 26.9; 3–258.6 ± 27.2; 4–255.0 ± 22.0; and 5–241.4 ± 53.2. There was no statistical difference in the functional results among the three treatment techniques. One patient operated on during the first postburn week later required arthrodesis and pinning of a proximal interphalangeal joint because of inadvertent exposure of the capsule and subsequent infection. The goniometric measurement of this fixed joint is included in the data for that group.

Because the patients in the previously described groups were felt initially to have deep partial-thickness dorsal hand injuries and would have been treated surgically, they were combined for comparison with therapy of full-thickness hand injuries (Table II). Thirty-eight hands with full-thickness injury were treated by early excision and grafting (Table II), while 15 were treated by topical chemotherapy, debridement, and later autografting of granulating wounds (mean postburn day of coverage, 32). While excision and grafting of full-thickness hand burns tended to produce poorer results than did expectant treatment with late wound resurfacing, the differences are just outside the range of significance. Four joints (all proximal interphalangeal) in the excised and grafted group required arthrodesis and pinning; functional measurements of these fixed are included in the data analysis and account for the numerically smaller range of motion for the excised and grafted group. Finally, no differences in functional differences could be detected by statistical analysis between treatment groups or between depth of injury groups.

TABLE II
Digital range of motion following treatment of partial- and full-thickness injuries of the hand

Digit	Partial-thickness Injury		Full-thickness Injury	
	Early E and G (n = 74)	Nonoperative (n = 37)	Early E and G (n = 38)	Nonoperative (n = 15)
W	122.5 ± 26.4	138.8 ± 17.2	109.1 ± 33.0	124.2 ± 24.2
1	107.3 ± 19.8	110.3 ± 19.7	89.5 ± 26.7	110.5 ± 18.3
2	230.9 ± 44.4	243.2 ± 20.6	210.4 ± 23.6	225.0 ± 23.6
3	245.5 ± 49.3	255.0 ± 27.2	218.8 ± 26.8	230.9 ± 30.1
4	244.8 ± 44.6	253.5 ± 24.7	217.4 ± 27.0	227.7 ± 29.9
5	234.6 ± 53.9	243.9 ± 43.2	200.7 ± 32.9	221.4 ± 34.4

Degrees, mean ± SD, W = wrist; 1 = thumb, etc.

Because of operative findings or clinical course, the admission diagnosis required reclassification of 75 of the 164 hands (46%) after the patients were entered into the prospective study. Forty-one hands thought to be deep partial-thickness injuries were more superficial in nature, while the remainder were divided between reclassification from partial-thickness to full-thickness injuries (15 hands) and from full-thickness to partial-thickness injuries (19 hands). All hands were measured within 24 hours of discharge (mean, 64 days; range, 14–163 days).

The effect of early surgery on patient mortality was examined by a binomial probability analysis based on age and burn size of the more than 6,000 admissions to this Institute. Of the 83 patients undergoing elective surgery, 16 died. The predicted mortality of these patients is 14 patients, with a 95% confidence interval of nine to 19 patients. Thus, early surgery per se did not seem to influence ultimate survival in this study.

DISCUSSION

In this prospective study both early excision and grafting and initial nonoperative treatment were equally effective in preserving function following thermal injury to the dorsum of the hand. Excision and grafting of hand with deep dermal burns, whether during the first or the second postburn weeks, offered no advantage over physical therapy and primary healing in maintaining hand function. Likewise, hands with more superficial burns responded equally well to operative and nonoperative treatment. While early excision and grafting of hands with third-degree burns tended to produce poorer results than did initial nonoperative care and late grafting, the differences are outside of the range of significance. In general, range of motion measurements of hands with full-thickness injuries tended to be less than similar measurements of hands with partial-thickness injuries,

but no statistical differences were demonstrated between these two groups of differing severity.

All joint measurements were made at the time of hospital discharge, which averaged 64 days following injury. Because of the referral structure of this Institute, continued care and rehabilitation are carried out by the referring facilities after prolonged consultation with the treating physicians and a detailed program for ongoing physical therapy. Although the discharge range of motion measurements in these patients indicated good functional results, most were below the ranges for normal digits. Salisbury and Wright (18) have found that such acceptable range of motion continues to improve during the first year following discharge. To prevent scar contracture, joint stiffness, and loss of motion, such improvements depend on conscientious physical therapy, careful supervision, and the rigorous use of compression garments during the first year following injury. Our program of in-hospital physical therapy is directed toward restoring range of motion sufficient to produce an adequately functioning hand, not toward attaining normal values. Past experience has indicated that attempts to attain the latter objective result in irreversible tendon and joint injuries.

Although reexamination of our patients at 1 year following injury would lend more strength to our current observations, we feel that any obvious treatment differences should be evident at the time of hospital discharge. The trend of the data, although statistically insignificant, suggests that early operative treatment may be less effective in preserving hand function than initial nonsurgical treatment. All fingers which required arthrodesis and pinning were in the excision and grafting groups and were associated with exposure of the joint capsule or injury of the extensor mechanism at the time of surgery. Although the number of such episodes (five digits) is too small to constitute a contraindication to early excision and grafting, this complication emphasizes the hazards of early excisional treatment, especially of full-thickness injuries, and the need for extensive experience in the treatment of thermal injuries of the hand.

Contrary to our expectations, early excision and grafting were not associated with increased patient mortality. Blood loss, whether or not a tourniquet was used, averaged approximately 1,300 ml, with many patients undergoing bilateral hand excisions losing in excess of 2,000 ml. Most procedures utilized general anesthesia. In spite of these stresses, the patients as a group tolerated this major surgery with no apparent effects on survival. These data contradict the clinical impression that patients with large burns are too unstable clinically to tolerate elective major surgery, and lend support to the safety of early excisional surgery for total body surface coverage.

As indicated by others (14), accurate assessment of burn wound depth during the first few days following burn injury proved to be quite difficult. Based on operative findings or clinical course, 46% of initial estimations of depth were erroneous. In particular, 41 injuries felt to be deep partial-thickness burns immediately following admission proved to be superficial in depth; such hands would be excised unnecessarily if early excision and grafting were carried out routinely. Misdiagnosis of deeper injuries was less common. Accuracy of burn depth estimation can be improved if excision is delayed until the end of the second postburn week. At that time, superficial injuries will have healed (or nearly so), and deeper burns will have become more demonstrable. Using this method, the proportion of superficial, deep-partial, and full-thickness burns in the prospective studies by Edstrom et al. (4, 5) was similar to that of our patients. Furthermore, they demonstrated that excision and grafting of deep dermal burns delays early return of hand function and offers no long-term advantage over spontaneous healing. That misdiagnosis of the depth of injury occurred in almost half our cases, even by highly experienced burn surgeons, indicates the extreme difficulty, if not impossibility, of designing a prospective study to assess early therapy of hand burns.

While this study was prospective in design, it was not randomized in the fashion of assigning patients to specific treatment groups by random numbers tables or other similar techniques. Each patient was randomly assigned to a primary surgeon, who then decided how the patient's hand burn should be treated. Patients with inhalation injury and larger burns tended to have no early hand surgery, although neither characteristic was a contraindication to early surgery. When compared individually, no selection bias could be ascribed to specific surgeons. The tendency to allow more severe burns (both total body and hand burns) to spontaneously debride and granulate was expected to bias such treatment toward poorer results; however, if anything, the hands treated by early excision and grafting tended to have the less desirable outcomes.

This study was carried out initially as a pilot project for a larger randomized prospective study. To properly design the latter study, information about the approximate measurement differences between groups and precision of the assessment techniques was needed. Based on the data from this patient series, the maximum treatment difference between treatment groups is likely to be no more than 10%. Given the variation of the measurements, 50 to 100 patients are required *for each treatment group* if a statistical measure with appropriate power is to find a real difference. Further, such a design presupposes complete diagnostic accuracy. Thus it is quite unlikely that a prospective study with adequate statistical design can demonstrate the superiority of either of these two techniques for treating dorsal hand burns. At the very least, a multi-institutional trial will be required to accumulate enough entries over a sufficiently short period of time.

Our data contradict the widely held belief that early

surgery better preserves hand function following thermal injury than does a more conservative approach emphasizing meticulous physical therapy and later wound coverge. Early excision and grafting of selected full-thickness injuries of the hands may be indicated in patients with small total body surface burns in order to shorten hospital stay (6). However, early surgical intervention in patients with massive burns should be directed toward area coverage, not toward hand excision.

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DISCUSSION

DR. DAVID M. HEIMBACH (Department of Surgery, Harborview Medical Center, Seattle WA 984): I would like to thank the Association for the opportunity to discuss this paper, and we welcome Doctor Goodwin to membership.

Doctor Goodwin and his coauthors from Brooke have addressed a very important and troublesome issue that we agonize over a great deal at our burn center. The issue, of course, is to figure out what priority to assign to coverage of the hand in the patient with a major burn. We know that precise autografting of a burn of the hand which includes all of the digits can use at least one half of an anterior thigh as the donor site. These areas might well be better used for broader coverage when life-threatening burns occur.

The authors at Brooke have been able to do a rather magical thing: They have been able to turn a prospective study into a retrospective study, in that they prospectively studied the hand burns but, as a matter of fact, rather than treating them by a protocol, each of the patients was admitted to surgeons in rotation, and each surgeon then treated the patients according to his own characteristics.

After the group of nonsurvivors and shallow burns and very deep burns were excluded, there remains a set of 19 excised hands to be compared to a group of 31 hands. The authors conclude that by using TAM measurements at the time of discharge, the results of conservative therapy with excellent physical therapy are at least as good as early excision and grafting.

Although it is hard for me to determine whether the depth data presented in both groups are really comparable, that may not make a great deal of difference, because in the real-life situation one must still go on clinical grounds to assess the depth of a burn.

Furthermore, the authors are to be complimented on using TAM (total active measurements) measurements of each digit in assessing hand burns, I wish everyone doing a series of hands would use such measurements because they are far more precise than just 'good' or 'excellent' range of motion. There are, however, several issues I would like to address to the authors.

First of all, since hands really only encompass about 5% of the total body area, one would not expect there to be any improvement in mortality figures in this group of patients by excising the hands. It is comforting to know, however, that the use of this prime donor site for the hands did not adversely influence mortality in the group.

The TAM measurements presented for each group of patients really fall well below the range of normal hand function. For patients with relatively smaller burns, but significant hand burns, we would expect hand function to be essentially normal at the time of discharge, unless the extensor mechanisms or joints are involved.

There are two bits of data that are also missing from the paper. One is the length of time it actually took those partial-thickness burns that were conservatively treated to heal. I would hope they would be least 3 weeks or longer, since we know we would not expect any difference in wounds that did in fact heal in less than 3 weeks. Furthermore, we should know whether the graft takes were really fully successful. Did they have a close to 100% graft take in their hands? We would not expect such good results if part of the grafts were lost.

Finally, since my departure from Brooke and my residency, I have either been blessed or plagued with the fact that my patients don't ever go away. They come back to me for followup. We have learned that the best results you get from hands are at the time of discharge, when the patient has been undergoing an extensive program of physical therapy under the direct supervision of a physical therapist visiting the patient two or three times a day. Unfortunately, when the patient comes back at 3, 6, 9, and 12 months, the results are often not as good as they were exactly at the time the patient goes home, particularly if one is dealing with thin skin that has just healed. Subsequent

scarring, and thickening of the scar, can cause significant loss of motion during the first 12 months. Only through careful followup for about 1 year can we really determine whether or not the patients have better results or as good results with hand function. We know that early excision of the hands in our studies and in other studies has dramatically decreased hospital stay, decreased hospital costs, and enabled patients to get back to work more quickly. On the other hand, these patients all had major burns in association with it, and would certainly have had their hospital stay prolonged for those reasons.

It is comforting to know, however, in this important group of patients with major large burns, that the results, at least at the time of discharge, are reasonably good, whether you treat them conservatively or aggressively.

Thank you.

DR. JOHN A. BOSWICK, JR. (University of Colorado Medical Center, Denver 80262): I would like to ask Cleon a continuing question in regard to secondary surgery—how many patients required secondary surgery in 6 months to a year?

I also congratulate you on excluding the two groups of patients; that is, those with very superficial burns which you know will be no problem, and those with extremely deep burns whose care is very controversial.

Of the 75 patients you reclassified regarding depth, in 41 you went from deep partial to somewhat more superficial, in 15 the reverse, and in 19 you originally classified as full-thickness to superficial. I think if we all take another look at our impression from the first 2 or 3 days, we would come close to these figures.

DR. ROGER E. SALISBURY (Plastic Surgery and Burn Center, Westchester County Medical Center, Valhalla, NY 10595): I would like to congratulate Cleon on a very nice paper which substantiates work that Marty Robson did several years ago and a study we did at the University of North Carolina. Essentially, we found that there is no difference in the final results between nonoperative treatment and early excision.

I have two questions. First, how did you control the variable of different surgeons operating on these patients, some of whom are certainly not hand surgeons? Did the same person come down and assist at each one of the procedures, or indeed did the same surgeon do them?

Second, the variable of function. In this study, power has been excluded as a way of following up these people. I point out that it is very important. In our series we found there was a difference in what happened to power from 6 months to a year following injury. It did even out at about a year, but power and range of motion did not return to normal by 6 months, as Doctor Heimbach pointed out, and it really took a year before full evaluation was possible. Did the authors consider using power and power pinch and side pinch as a way of evaluating results?

DR. CLEON W. GOODWIN (Closing): I would like to thank the discussers for their comments. In reply to Doctor Heimbach's questions, we really did not expect any improvement in mortality with this procedure. In fact, we approached this with the initial thought that a general anesthetic and excision requiring 1,000 to 1,500 ml of blood during the first postburn week would have had a detrimental effect on patient survival. We did not find this, which was a surprise to some of us.

Several discussers pointed out potential problems with range of motion measurements and their prognostic significance at the time of discharge. Our institution is a primary referral facility for acute care and any necessary immediate reconstructive surgery. We see very few of these patients in followup. Of the 98 patients studied, fewer than 20 live in the San Antonio area who were potentially available for evaluation. Such a group is very difficult to analyze because of their small number. Several who have returned have maintained their discharge function when they were reevaluated.

Doctor Salisbury pointed out, in a paper which was published this year, that discharge hand function improved considerably during the first year after discharge. Rather than expecting deterioration of the discharge range of motion measurements, I would expect the patients to maintain that range of motion or even to demonstrate some improvement in the year following discharge. To complete the answer to Doctor Salisbury's question, we did not use power pinch measurements.

How long did it take deep second-degree burns to heal? That is a very difficult question. A number of the patients who were thought to have deep second-degree burns were excised and grafted during the first postburn week. Those whom we felt to have deep dermal burns and were not operated on early healed generally during the third postburn week. We felt that these could legitimately be called deep dermal burns.

Although I did not mention it in the paper, the percentage of graft take was 92% for the patients excised and grafted early. Some patients did not have a 100% take and required additional surgery, but for most, universal acceptance of the grafting was achieved. We did not keep a record of the number of subsequent procedures needed by these patients. A touch-up procedure was required on the patients where there was some graft loss.

Doctor Boswick asked about the exclusion of patients with superficial partial-thickness burns. We initially approached this as a preliminary study with the goal of collecting data so that we could design a randomized study evaluating early excision versus the initial nonoperative approach. It became obvious when selecting patients and stratifying them according to depth of injury that there was considerable inaccuracy in judging the depth of injury immediately following burn injury. This persisted throughout the study and helped to convince us that a prospective study would require a large number of patients and be difficult to carry out.

Finally, I would like to thank the members for the privilege of presenting this paper.